Are M Dwarfs Viable Targets for Planet Finding & Do We Care?

by Angelle Tanner (JPL/CIT)

- Are they there?
- Can we find them?

Why M Dwarfs?

1)There are lots of them

Out of ~348 stars in 10pc there are 239 M dwarfs and 21 G dwarfs

2) They are light

For a given planet mass and distance the gravitational perturbation on an M dwarf is larger than a G dwarf

3) They are old

Habitable zones are potentially stable for Gyrs

However, they are faint, cool and have active photospheres

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Recently Endorsed by the Exoplanet Task Force !!!

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Core Accretion

Core accretion is unable to form Jupiter-mass planets around low-mass stars since the timescale necessary to form the planet is longer than the lifetime of the protoplanetary disk.

While Jovian planets may be rare, Neptune and Earth-mass planets may be common

Laughlin et al. (2004)

Terrestrial-mass planets are less likely to form around low-mass stars due to a smaller reservoir of material. The odds of forming the planet in the habitable zone are small.

Raymond et al. (2007)

Disk Instability

- IF M dwarfs do have a large number of gas giants, then we should assume they formed through disk instability, if not then maybe the disks are not massive enough

- Disk instability is not the likely method for forming Neptune mass planets

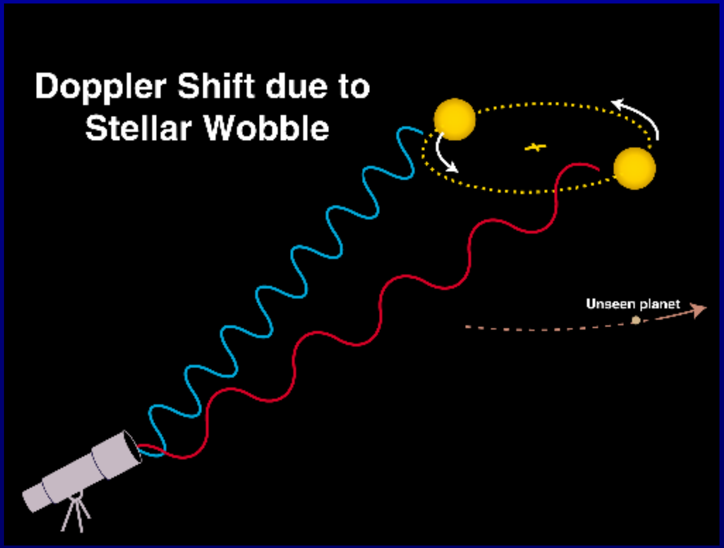
Boss et al. (2006)

Radial Velocity

A super Earth (10 $M_{\oplus}$) in a 1 AU orbit makes a radial velocity signature of 3 m/s around an 0.1 $M_{\odot}$ M dwarf compared to 1 m/s around a 1 $M_{\odot}$ G dwarf.

M dwarfs with reported RV planets:

- GL 176 (M2.5V, 9.4pc, 24 Earth masses)
- GL 317 (M3.5,9.7pc, 2? planets)
- GL 518 (M3,6.26pc, 3 planets, smallest yet, in HZ)
- GL 876 (M4,4.72pc, 3 planets - 1 Jupiter)
- GL 849 (M3.5, 8.8pc - 1 Jup)
- GL 436 (M2.5, 10.2pc)
- GL 674 (M2.5, 4.54 pc)
- HD 41004 (M2, 43pc)



Original Surveys focused on FGK stars but are now observing more M dwarfs (147 at Keck)

Surveys for hot Jupiters around M dwarfs

While the original RV surveys focused on FGK stars, more effort is being devoted to M dwarfs

Endl et al. (2006)

- Looked at 90 M dwarfs with RV precision of ~2.5 m/s and found no planets with Msini>3.8 M_J at a < 0.7 AU

- They used observations from the HET, Keck and VLT telescopes

- They conclude that the frequency of such planets is <1.27%

The Future - IR RV Surveys

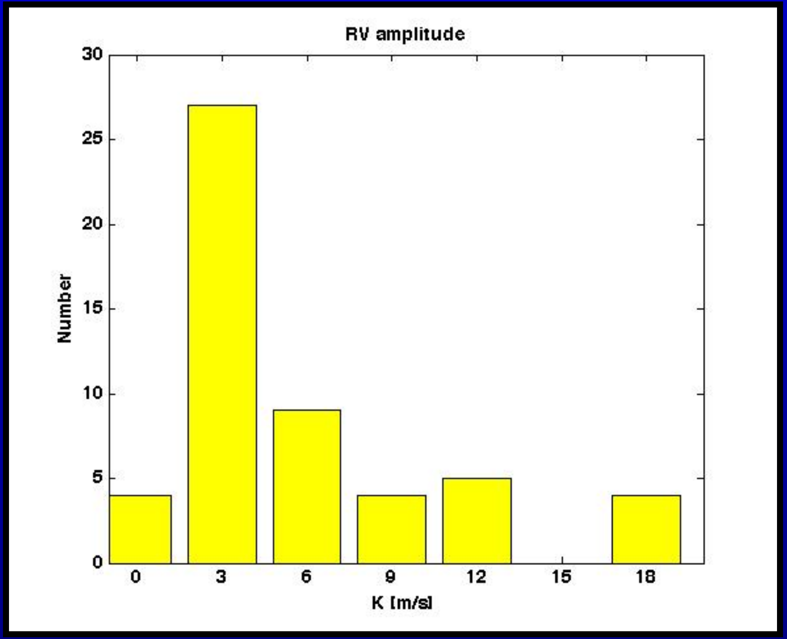
- M dwarf flux peaks in IR

- Contrast ratio of star spots is smaller in IR resulting in less of an influence to RV signal (Eiroa et al. 2002)

- VLT's CRIRCES - 75 m/s RV precision

- Externally dispersed interferometers (EDI) are being designed to achieve <5 m/s precision in 10 minutes for H≥10 (Edelstein et al. 2007)

- HARPS-like instrument for Gemini -PVRS (collaboration) - 1 m/s at J,H and K - ?????????



RV amplitude of a sample of 60 nearby M dwarfs with $1M_{\oplus}$-$1M_J$ planets in the HZ

Direct Imaging

Direct detection of a 10 M_J planet around a 100 Myr M dwarf requires a contrast of $\Delta K = 10.5$ opposed to 13.9 for a G dwarf

- Two of the four "planets" imaged around young stars have M type primaries - SCR 1845 & 2M1207 (Biller et al 2006; Chauvin et al. 2005) - prolly more

- Many folks have done high contrast imaging surveys - i.e. Apai doing a 6pc M dwarf survey in the L band with the MMT

- L. Close and N. Law have done surveys which Found many VLM binary systems

- Instruments: Gemini/GPI, VLT/SPHERE, MMT, Gemini/NICI, JWST

- Should be able to get to 1 M_J planets around mid-late type Ms

Transits

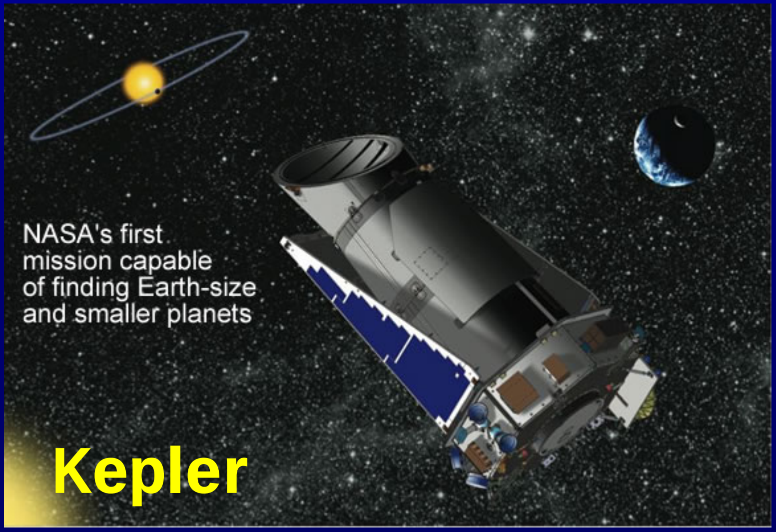
A super Earth ($R=2R_{\oplus}$) will make a transit depth of 1/25 around an M dwarf compared to 1/120 for a G dwarf

- The faintness of the M dwarfs means that a planet of a given size will have a deeper transit depth than that for an earlier type star

- Transits are more likely to occur around M dwarfs ~1-3%

- Plavchan et al. have used 2MASS calibration data to find a host of eclipsing M dwarf binaries and two exoplanet candidates

- Originally, Kepler did not include many M dwarfs in its sample. That has been changed - and others are considering their potential



The first terrestrial planet in the HZ will be found by an M dwarf transit survey?

MEarth project

- 2000 late-type M dwarfs
- 10 30 cm telescopes
- 3 year duration
- 2.6 planets for 10% occurrence rate

-Nutzman & Charbonneau (2007)

Find planets through transits and
Characterize with RV and Spitzer/JWST follow-up

JWST will characterize planets found in M dwarf transit surveys

- Transit photometry - planet radius/density
- Emission spectra - via 2ndary eclipse
- Transmission spectra - planetary atmospheres
- Reflection spectra

- Characterize the atmospheres of the terrestrial planets as well?

If we know the radius to better than 5% and the mass to better than 10%, we can distinguish between ice and rocky planets (Valencia et al. 2007)

Astrometry

An 5 $M_{\oplus}$ planet at 1 AU will make an astrometric signature of 4 μas around an M dwarf compared to 1.5 μas around a G dwarf.

- M dwarfs are good targets for astrometry since they are light and, therefore, have larger astrometric signals

- STEPS is an astrometric survey of M dwarfs at Palomar (Pravdo et al. 2006)

- Future Carnegie and Palomar surveys to aim for 100 μas accuracy (Cameron et al. 2008)

- Future ground-based astrometric surveys could get down to 10 μas single measurement accuracy (I.e. Keck/VLT, Seifhart et al. 2007)

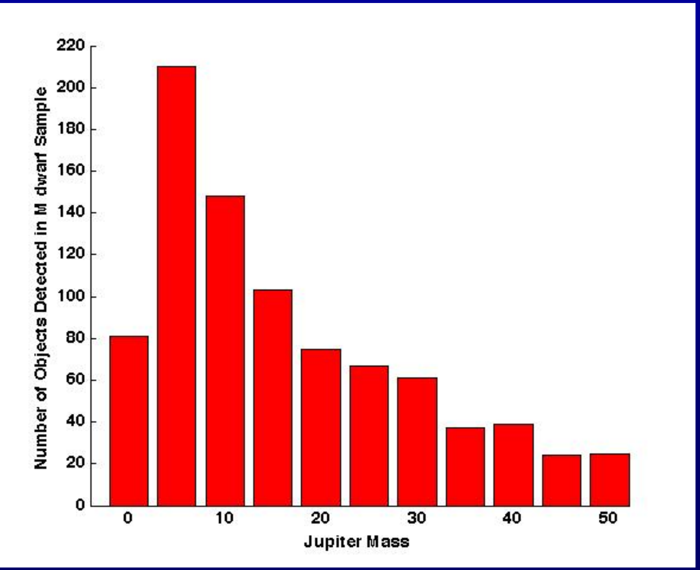
M3 dwarf binary G78-28AB

Astrometric Survey with Kepler

Kepler is expected to have an astrometric accuracy of ~100 mas. Unremarkable, except for the fact that it will make a measurement every 30 minutes for 5 years

Assumptions:

- 100K 2-D observations with 100 mas single measurement accuracy
- Can make into 100 2-D 63 μas obs
- Mass range of 1-60M_J
- 1630 M dwarfs with distances of 25-365pc
- Chosen based on 2MASS colors and proper motions



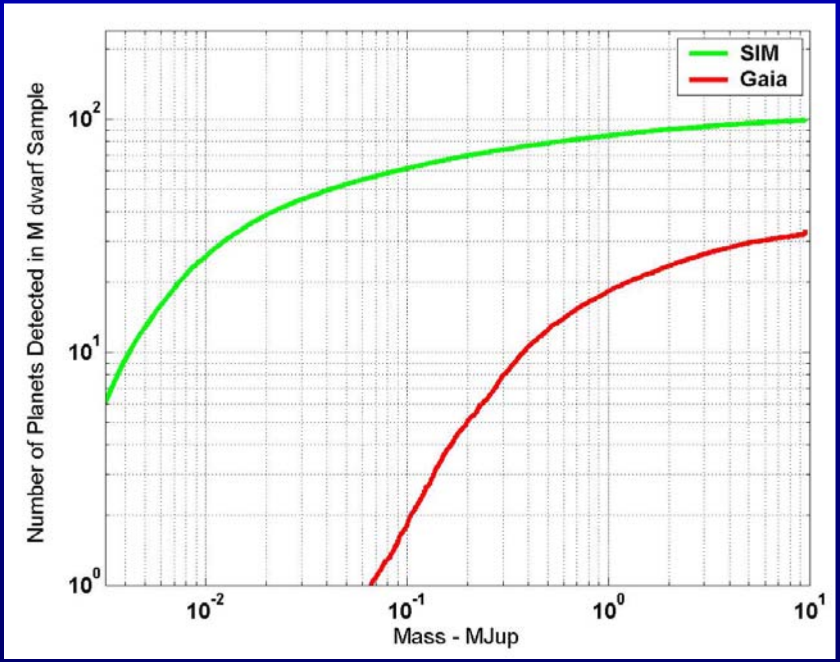
What SIM can do...

M dwarf Sample:

- 100 of the nearest M dwarfs taken from the RECONS survey (Henry et al. 2007)
- Distance = 1-10 pc
- SpTy = M1-M9V
- 7.3 < V < 15

SIM detects all planets with masses of 1-10 Me and periods of 0.2-5 years

And estimates 31% of their masses to within 30%



Summary

• Some predict that the first truly rocky/terrestrial planet will be found around an M dwarf

• Various JPL/NASA missions will focus on M dwarfs as "easy targets" to test observational methods

• The limits of planet detection around M dwarfs due to stellar granulation, flares and star spots still needs to be fully assessed

• The runts of the local neighborhood may yield the greatest discoveries!